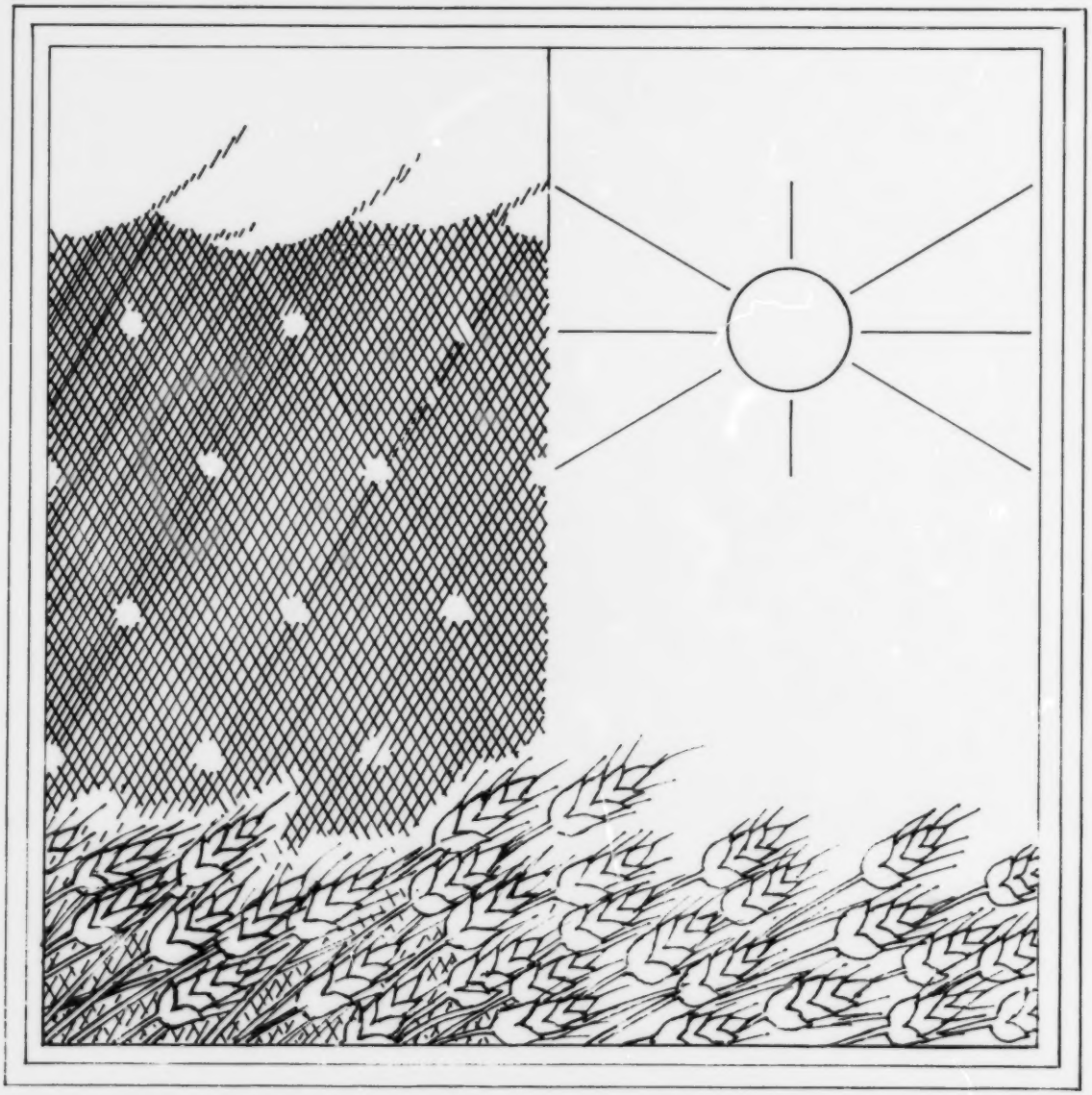
EFFECTS OF HAIL AND DROUGHT ON MAJOR CROPS IN ALBERTA



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EFFECT OF HAIL AND DROUGHT ON MAJOR CROPS IN ALBERTA

by

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I. BACKGROUND

Hail has been and continues to be a major cause of loss to crops grown in Alberta. In 1983 the total loss payout by Alberta Hail and Crop Insurance Corporation (AHCIC) for hail damage was $37 million. This total payout only represented the loss to those farmers who insured with AHCIC. Moreover, the payout did not cover the total loss of farmers submitting claims, being limited by various deductibles and coverages. Drought has also been a major cause of crop loss for Alberta farmers particularly during the past few years. Under the all risk crop insurance, the total loss payout for damage caused by drought was just over $25 million, 50 per cent of total payout in 1983. These annual losses due to hail and drought by no means represent the total loss experienced by Alberta farmers, but they are, nonetheless, indicative of the magnitude of the hail and drought problem in Alberta.

Cloud seeding to suppress or reduce hail damage has received much attention throughout North America. In Alberta, the Alberta Research Council (ARC) has been researching weather modification since 1969. Their main thrust was directed at hail suppression and the seeding of rain clouds. Because major crop damage was caused by hail, it was felt that the research and weather intervention would be well received by those affected and the scientific community.

The ARC has just completed five years of intensive study of weather modification and is preparing a detailed technical report for submission to the Minister of Agriculture. In conjunction with this technical report, the Alberta Weather Modification Advisory Committee requested that the Production and Resource Economics Branch attempt to estimate the annual economic loss from hail and drought to Alberta farmers. This report therefore examines the economic impact of hail and drought on Alberta farmers.

II. OBJECTIVES

This study is primarily concerned with the annual loss to Alberta farmers from hail and drought, and the costs associated with an appropriate weather modification system for Alberta. The paper attempts to answer the following questions:

- On average, how much agricultural production is lost annually to hail and drought in Alberta?
- What is the value of this annual loss?
- To what extent can the weather be modified to reduce this loss?
- What is the cost of implementing an appropriate full scale provincial weather modification system?
- What are the net benefits of such a weather modification system?

III. SOURCE OF DATA

Alberta has a very diverse and complex agricultural industry. Production ranges from poultry to cattle to wheat, with literally dozens of mixed operations in between. Hail and drought affect many of these enterprises directly through crop loss and indirectly through increased feed prices to cattlemen resulting from reduced feed supplies. Within the scope of this study, it is not possible to evaluate the possible effects of hail and drought on all of these enterprises. Due to time and data constraints, only the major cereal and oilseed crops of Alberta are considered. A more cursory (qualitative) approach was used for the livestock, forage and special crops.

Hail Loss Data

The AHCIC has been involved with hail insurance for 20 years. During this period, it has collected a considerable amount of data pertinent to hail damage. At the same time, many changes have occurred in the insurance system, record keeping and farmer participation. Moreover, the available data are not readily and directly adaptable to measure hail damage. Consequently, there are limitations to the use of these data for estimating hail damage.

The AHCIC data used in this study included the following:
- Straight hail insurance for years 1980-85.
- Hail endorsement statistics for years 1980-85.
- Hail payout from all-risk crop insurance 1979-85.
- Loss to premium and loss-to-risk ratios 1980-85.
- Average yields by risk area and major crop.

The limitations of these data are presented later. Some limited information was also obtained from private insurance companies.

Drought Loss Data

Drought and the threat of drought have always been a part of prairie agriculture. Many research projects have been done to help alleviate the risk of drought to prairie farmers (drought resistant crops, economics of various crop rotations, etc.). However, there are no comprehensive studies on the specific question of "how much does drought cost farmers in Alberta?". Due to time limitations, such an analysis was not within the scope of this study. We have however, provided a very "broad brush" approach to costing drought in Alberta. The results should therefore be viewed in this light.

The data used for the drought analysis were:
- AHCIC yield data for major crops, 1973 - 1984.
- AHCIC crop insurance data; losses, premiums, risk written.
- Statistics Canada area estimates for crop production.
- Statistics Canada data for 1985 yield data.

Other Data Sources and Study Area

There are no full scale operational weather modification systems which would compare in size to what is required for Alberta. Alberta contains over 20 million acres of cropland. Equally important, weather modification is still in the experimental stage. As a result, the task of designing and costing such a system is no easy matter. In this study, the ARC provided cost estimates which were subjected to conventional accounting and financial methods used by Alberta Agriculture.

The ARC has conducted a research and operational cloud seeding program for the past 11 years. The research was mostly conducted from Edmonton south to Red Deer, while the operational seeding was done between Red Deer and Calgary. The program area was chosen because of its historically high incidence of hail storms. The proposed full scale weather modification system was derived from the experience gained from the ARC projects.

AHCIC insures crops and charges premiums according to 14 basic risk areas. These risk areas follow municipal boundaries where appropriate, usually excluding tracts of non-agricultural land (Figure 1). Much of the data collected by AHCIC is tabulated by county and by risk area. The analysis of hail damage and loss recovery used annual data which were aggregated to the provincial level. The drought analysis however, shows breakdowns by risk area to illustrate the more drought prone areas in Alberta. Acreages seeded and harvested by census division are available from Statistics Canada. For this reason some of the drought analysis was done according to census division. Figure 1 shows the AHCIC risk areas and Statistics Canada census divisions.

Other sources of data included Agriculture Statistics Yearbook, published by Alberta Agriculture, and personal communication with individuals familiar with crop insurance in Alberta.

Data Limitations

Hail

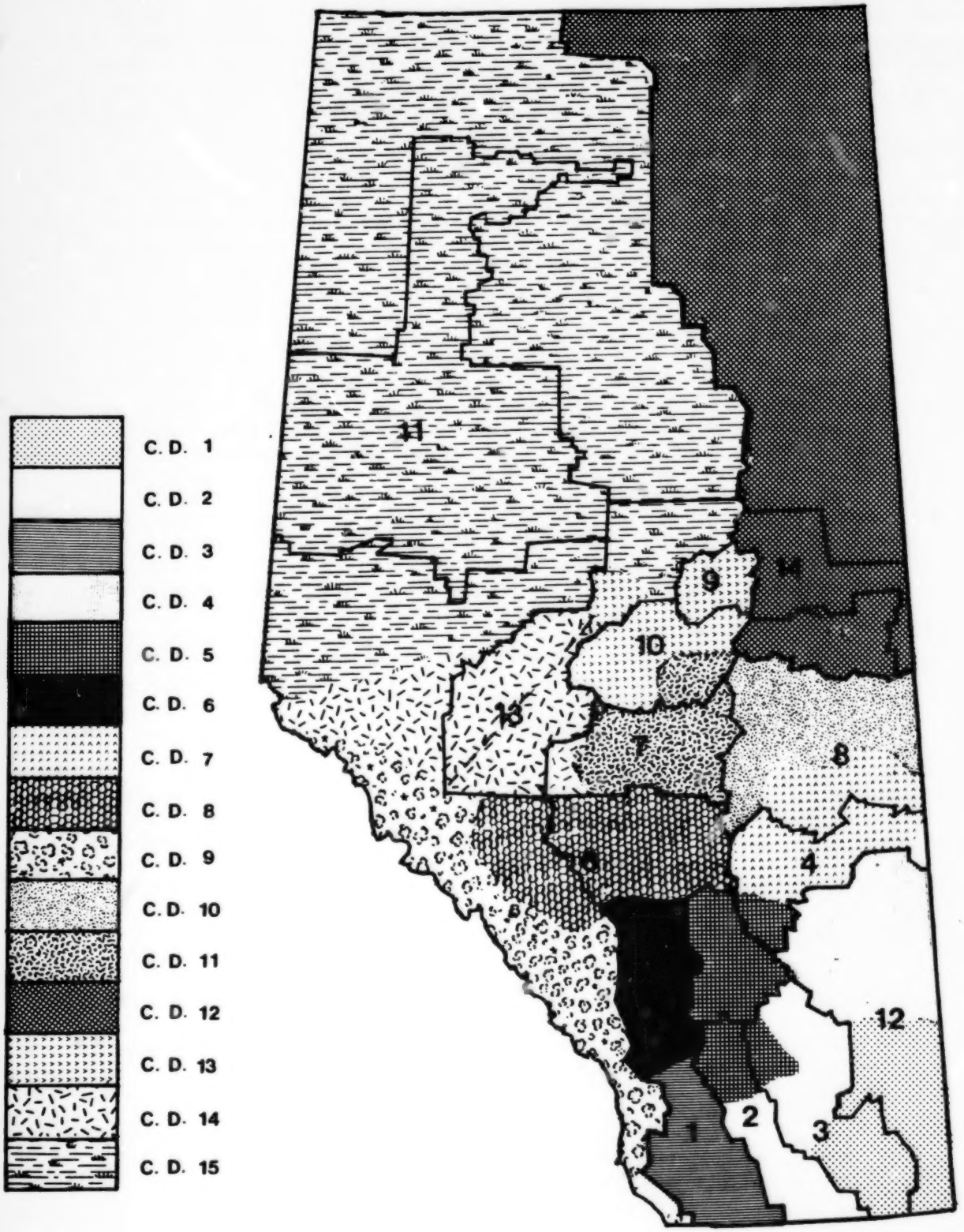
Even though hail causes substantial damage to agricultural crops in Alberta, one cannot decipher the full extent of crop loss from available provincial crop reports or data published by Statistics Canada. The best available source is the AHCIC data. These data, which consist of total risk, total acres insured, premiums and total loss paid out, form the basis of the analysis of crop loss due to hail.

As indicated above, there are several shortcomings in using the AHCIC hail data for evaluating <u>total</u> hail damage. The major problems are as follows:

- Not all farmers insure their crops for hail or all-risk coverage.
- The insurance program is not aimed at covering potential loss in output value, but rather to cover a portion of production costs (operating costs).
- There are various levels of coverage and deductibles under the different crop/hail insurance schemes. These restrictions tend not to reflect the true loss of production from hail.

FIGURE 1

Overlay of Census Divisions and Risk Areas



- Depending on the extent of the damage, producers may not submit claims since such claims have a bearing on subsequent premiums, etc.
- While the acreage affected is known, the actual amount of yield loss is not available.
- There is no information on the loss in grades.

The analysis therefore adjusted the numbers to more closely reflect the total potential crop loss due to hail.

Drought

Long term average yields along with specific comparison to drought years were used to approximate total damage of the major cereal/oilseed crops of Alberta. A matrix of average production and potential losses due to drought was derived. This matrix gives a broad estimation of the past loss of major cereal/oilseed crops due to drought. To what extent this represents total potential loss is not clear; a more in depth study on weather and the associated yields would be necessary to answer this question.

A brief analysis of the AHCIC data is also provided to see what portion of total loss payout was due to drought, and the average annual payout. The past two years were closely examined, since farmers were hit hard with extensive drought during this period (1984 and 1985).

IV. METHOD OF HAIL ANALYSIS AND RESULTS

No statistics are available on total direct crop damage caused by hail. The Alberta Hail and Crop Insurance Corporation (AHCIC) does, however, provide hail insurance for many agricultural crops grown in Alberta. AHCIC has readily accessible data on the hail program for the period 1980 to 1985. The data include loss (payout), premiums, and total risk for all crops by risk area. Because there is no direct measure of total crop production loss due to hail, four possibilities for estimating the cost of hail to Alberta farmers were considered. These are:

A. Willingness to Pay (WTP): the total amount farmers and society (through government) are willing to pay for protection against the risk of hail via hail insurance.

B. Total Adjusted Loss Payout (TALP) by AHCIC for insurance claims against hail damage.

C. AHCIC Loss-to-Risk applied to total value of crop production.

D. AHCIC Loss-to-Risk applied to total risk written by AHCIC.

Willingness to Pay (WTP)

WTP is a method used by economists for estimating the value of non-market resources which are difficult to price. Economists who measure the value of wildlife, for example, use hunters WTP as a proxy for the value of these resources. Outdoor recreation at public recreation areas may be similarly valued. In this study, the measure of WTP is the premiums paid by farmers and federal government for crop insurance, and the administrative cost of the program which is paid by the Alberta government. Limited hail insurance is also provided by private companies and these premiums are included in the WTP. This total expenditure reflects society's total WTP for protection against the risk of hail damage.

The potential value of crop production loss due to hail can be estimated by the willingness of farmers to pay for crop loss protection insurance or their willingness to accept compensation for crop loss (WTAC). The amount a farmer is willing to pay for risk protection against hail damage is related to income level and stability, equity position, cost of the insurance program, and effectiveness of the program. Clearly, the amount a farmer is willing to accept for compensation will be higher than the amount he is willing to pay for protection. WTP has income constraints whereas WTAC does not. This study uses the WTP concept, since the WTAC approach is more appropriate where accessibility to resources is being curtailed or eliminated.

Where WTP is used for evaluating wildlife resources, data collection can be costly and time consuming (mail out questionnaires, field interviews, etc.). In this study, we were fortunate to have crop insurance data where premiums paid by farmers and government can be used as a proxy for society's willingness to pay for crop protection against

hail and drought. Table 1 shows the breakdown of hail insurance premiums and acreages (for straight hail and hail endorsement) for the total province. The premiums include the payments of farmers and the federal government. The Alberta government covers administrative costs, which are listed in Table 1.

TABLE 1: HAIL INSURANCE PREMIUMS AND ADMINISTRATION COSTS*

	1980	1981	1982	1983	1984	1985
	- - - - million - - - -					
Straight Hail						
Premium ($)	13.14	16.63	17.58	17.18	16.22	15.80
Administration ($)	2.05	1.78	2.14	2.65	2.20	2.04
Acres	2.80	3.43	3.67	3.70	3.39	3.30
Endorsement						
Premium ($)	24.47	41.79	29.67	36.06	42.44	46.73
Administration[1] ($)	1.84	1.78	1.75	1.35	1.60	2.17
Acres	5.18	5.76	5.78	6.93	8.12	9.22
All Risk[2]						
Premium ($)	10.70	10.22	12.85	7.91	4.61	1.56
Administration ($)	0.83	0.80	0.99	0.62	0.42	0.15
Private Insurance						
Premium ($)	10.79	10.79	10.79	10.79	10.79	10.79
Acres	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Total Prem & Admin ($)	63.82	83.78	75.78	76.57	78.29	79.24

* All premium and administration costs are in 1985 dollars.

The six year average annual premium collected, including the administrative costs, was $75.2 million. Therefore, the imputed average annual value of hail damage to society is at least $75.2 million, or $6.07 per acre (assuming 12.56 million acres).

[1] Administration costs for hail endorsement were derived by prorating total administration costs by the proportion of claims made to the endorsement program.

[2] Premiums and administration costs for hail payouts under all risk are derived by multiplying total premiums and administration costs by the percentage of total payout due to hail.

Total Adjusted Loss Payout (TALP)

The TALP approach involves adjusting loss data for coverage levels and for farmers who do not insure, to arrive at an estimate of total loss to crops due to hail. This approach will undoubtedly underestimate the true costs of hail for the following reasons:

- It is not feasible to measure effects on all crops (i.e. pasture, forages etc.)
- It is difficult to know the full extent of hail damage because of the absence of information on hail damage on farms which do not insure.
- Indirect costs of hail damage are not measured. These would include, for example, the loss to livestock producers who are forced to buy feed on the open market at hail induced prices.

To achieve the most complete analysis of crop loss due to hail, four major options of crop insurance were examined. The four options[1] were:

i) Straight hail insurance (AHCIC).
ii) Hail Endorsement (AHCIC).
iii) All Risk portion paid out as a result of hail (AHCIC).
iv) Private hail insurance.

Six years of data between 1980 and 1985 were used in the analysis.

Crop losses under these insurance schemes are given in Table 2. Private insurance payout was based on the AHCIC 1980-85 loss-to-premium ratio of 79.5 per cent. This was done because the information on premiums paid and the loss paid out by private insurers were only available for 1983, which happened to be a net loss year for private insurance companies. The average annual losses paid out to producers as a result of hail damage was estimated at $93.0 million. No acreage data were available for hail damage payout under all-risk. However, all other programs would consist of about 12.6 million acres of insured crops. At an average annual loss of $93.0 million spread over 12.6 million acres, the average annual crop loss was estimated at about $7.40 per acre.

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[1] For a more detailed discussion on how crop insurance works in each of these categories, see "Crop Insurance What Is It? Should I Buy It?", Alberta Agriculture, AgDex 838-6.

TABLE 2: ANNUAL CROP LOSSES DUE TO HAIL

	1980	1981	1982	1983	1984	1985	Average
			- - - - million dollars - - - -				
Straight Hail	8.77	8.65	21.54	12.99	16.66	7.74	12.98
Endorsement	24.63	26.08	36.46	27.52	39.51	23.44	29.67
All Risk	4.34	3.14	8.89	7.67	14.29	5.18	7.11
Private	8.58	8.58	8.58	8.58	8.58	8.58	8.58
Total	46.32	46.44	75.47	56.76	79.04	44.95	58.29
Total Adj. Losses*	73.88	74.07	120.37	90.53	126.06	71.69	92.97
			- - - - million acres - - - -				
Acreages	10.33	11.53	11.80	12.96	13.86	14.86	12.56

* AHCIC data revealed that the weighted average coverage level taken by Alberta farmers was 62.7%. Assuming that the payout was equal to 62.7% of the total crop loss, then the AHCIC loss must be adjusted upwards to reflect the full value of crops damaged.

AHCIC Loss-to-Risk and Total Crop Production

Table 3 shows the estimated total damage to field crops in Alberta as a result of hail. This method of analysis assumes that, on average, all field crops in all regions experience the same provincial loss to risk ratio. For example, in 1975 the total value of field crops in Alberta was $1.697 billion. The loss-to-risk ratio for 1975 was 4.88 per cent, which translates into a crop value loss of $180.1 million in 1985 dollars. Notice that all crop values in column B are indexed to 1985 constant dollars (column C).

Three sets of averages were calculated at the bottom of Table 3. It was felt that a 15 year average (1971-85) would be appropriate for use in the economic analysis. In that period, the loss-to-risk ratio was 4.22 per cent and the estimated average annual value of total crop lost to hail was $134.4 million (in 1985 dollars).

TABLE 3: ESTIMATED HAIL DAMAGE TO FIELD CROPS IN ALBERTA, 1961-1985

Year	CPI Index	Value of Field Crops		L/R Ratio	Hail Damage (1985 $)
		Current Dollars	(1985) Dollars		
	A	B	C	D	E
		-million-	-million-	- % -	-million-
1961	31.7	414	1,661	3.70	61.47
1962	32.0	471	1,872	4.30	80.51
1963	32.6	563	2,197	4.40	96.66
1964	33.2	524	2,008	2.00	40.15
1965	34.0	592	2,215	4.00	88.59
1966	35.2	742	2,681	8.02	215.04
1967	36.5	586	2,042	2.60	53.10
1968	38.0	615	2,059	2.26	46.53
1969	39.7	529	1,695	3.12	52.88
1970	41.0	530	1,644	4.68	76.95
1971	42.2	560	1,688	6.25	105.50
1972	44.2	786	2,262	4.36	98.62
1973	47.6	1,537	4,107	2.36	96.93
1974	52.8	1,479	3,563	2.79	99.41
1975	58.5	1,697	3,690	4.88	180.07
1976	62.9	1,671	3,379	4.12	139.22
1977	67.9	1,470	2,754	3.50	96.38
1978	73.9	1,908	3,284	4.31	141.55
1979	80.7	2,330	3,673	4.90	179.96
1980	88.9	3,047	4,360	3.96	172.64
1981	100.0	3,005	3,822	3.06	116.96
1982	110.8	2,571	2,952	6.67	196.87
1983	117.2	2,999	3,255	4.51	146.80
1984	122.3	2,725	2,834	6.29	178.27
1985	127.2	2,153	2,153	3.10	66.74
1961-85	62.0	1,420	2,714	4.17	113.11
1971-85	79.8	1,996	3,185	4.22	134.39
1980-85	111.1	2,750	3,229	4.53	146.38

Source: Alberta Agriculture Statistics Yearbook and AHCIC data.

AHCIC Loss-to-Risk and Total Risk

This method combines the average annual hail risk written by the AHCIC and the long run loss-to-risk ratios to estimate crop damage. The method is quite similar to C, except for the use of risk written by AHCIC instead of total value of crop production. Table 4 shows the risk written and the overall weighted average risk written for the 10 years, 1976-85. Risk data were not available for 1971 to 1975.

The average annual risk written was $873.7 million. Using the 1971-85 loss-to-risk ratio of 4.22 per cent derived in method C (Table 3), the average annual crop loss would be $36.8 million, adjusted to $58.8 million for the 62.7 per cent coverage level of policies.

TABLE 4: RISK WRITTEN FOR HAIL BY AHCIC[1]

Year*	Straight Hail Risk	Straight Hail Acres	Hail Endorsement Risk	Hail Endorsement Acres	Hail Under All-Risk Ins. Risk[2]	Hail Under All-Risk Ins. Acres[3]	Total Risk
	$'000	'000	$'000	'000	$'000	'000	$'000
1976	236,984	3,238	298,352	3,473	36,521	5,330	571,857
1977	175,116	2,404	347,741	4,230	41,237	6,284	564,094
1978	246,708	3,355	318,568	4,239	35,172	5,908	600,448
1979[4]	203,561	2,851	330,614	5,881	113,740	5,882	647,915
1980	225,110	2,803	426,788	5,184	112,314	6,640	764,212
1981	296,419	3,426	791,044	5,762	115,538	7,009	1,203,001
1982	308,725	3,670	527,611	5,785	158,985	7,204	995,321
1983	287,594	3,692	606,099	6,925	100,111	8,289	993,804
1984	262,750	3,394	635,780	8,117	60,932	9,292	959,462
1985	243,356	3,302	754,292	9,215	18,987	10,677	1,016,635
Ave. Weighted	253,090	3,214	542,981	5,881	77,642	7,252	873,713

* All years are indexed to current dollars (1985).

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[1] No information was available on the risk written by private insurance companies.

[2] Hail payouts under all-risk for 1976-78 were estimated using 1979-85 hail/payout.

[3] This acreage represents the total acreage under all-risk coverage not hail coverage.

[4] Endorsement acreage for 1979 was not available, therefore averages of other years were used.

V. METHOD OF DROUGHT ANALYSIS AND RESULTS

Annual yield data from AHCIC for the years 1973-85 were used to select "optimum" benchmark yields for the drought analysis. The optimum yield for each crop was chosen by taking the average of the three highest yields recorded in the 13 year series. The major crops considered were wheat, oats, barley and canola. The 13 year AHCIC yield data were also used to generate random 20 year annual yield data series for each crop. Annual deviations of the latter yields from the corresponding optimum yield were next computed for each crop, and these yield differences were converted to revenue lost by using the 1985 average acreage and unit market price. Indeed, 400 20 year yield data series were computed for each crop, and it is the average discounted value of the 400 yield differences that is given in Table 5.

TABLE 5: ESTIMATED VALUE OF DROUGHT CROP LOSS IN ALBERTA

CROP	AREA PLANTED	OPTIMUM YIELD	DROUGHT DAMAGE
	'000 ac.	bu./ac.	$'000
WHEAT	7,450	32.3	1,476,960
BARLEY	5,200	48.5	859,961
OATS	1,200	57.5	132,480
CANOLA	2,800	22.2	714,447
TOTAL	16,650		3,183,848

Over the twenty year period considered, the total discounted deficit value for all crops was over $3.18 billion. This translates into an average annual equivalent cash flow of $255.5 million.

The estimate of $255.5 million is obviously an overstatement of the effect of drought on crops in Alberta, because drought is not the only factor affecting optimum crop production. Some of the constraints to reaching optimal production are frost, heat units, wind, excess moisture, insects, and hail. All of these factors account for some portion of the crop deficit forecasted.[1]

AHCIC 1979-85 data show that the percentage of total losses paid out as a result of drought totalled about 76 per cent. However, in this seven year period, Alberta farmers experienced two severe drought years (1984 and 1985). If 1984 and 1985 are deleted from the total, the

[1] We chose the average of the best three year yields (bu./ac.) for each crop as a proxy for optimal.

percentage of losses paid out as a result of drought drops to 50 per cent.

Using 50 per cent as the average payout of losses due to drought, the 20 year present value of $3.18 billion can be adjusted to $1.59 billion, assuming the remainder of the crop deficit is due to other causes (hail, frost, etc.). The total 20 year discounted crop deficit of $1.59 billion represents an annual equivalent cash flow of $127.6 million.

An attempt was also made to value possible hay production losses due to lack of moisture.[1] Alberta Agriculture Statistics Yearbook data were used to estimate hay yields and production in Agricultural Reporting Areas 1 - 3 (Southern Alberta). The approach used was the same as for the cereal grains: annual yields for the years 1973-85 were used to select the optimal yields and to randomly generate a 20 year yield data series. Again 1985 estimated acreage and average market prices were applied to the deviations from the optimum yield. These values were in turn discounted to obtain the present value of the estimated loss of hay production due to drought. The present value of the hay production deficit over the 20 year period was estimated at $501.8 million, corresponding to an annual equivalent cash flow of $40.3 million.

This total hay production deficit is affected by the same agro-climatic constraints as mentioned earlier for grains. Drought undoubtedly has the largest impact on hay production, especially in the area under consideration (A.R.A.s 1-3). Causes of hay production deficits other than drought (hail, excess moisture, etc.) are estimated to be 25 per cent of total damage, therefore 75 per cent of the damage, or $30.2 million, was attributed to drought (compared to 50% for grains).

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[1] It should be understood that hay production is very diverse in terms of the type of hay, quality and yields.

VI. A WEATHER MODIFICATION SYSTEM FOR ALBERTA

Current Research and Operations of Weather Modification in Alberta[1]

Between 1974-75 and 1985 Alberta had an extensive research and operational weather modification program. During this period, the ARC's study area was divided into two sections (see Figure 4). Operational seeding was carried out exclusively in the southern half of the study area. The operational seeding program essentially seeded every hailstorm which was determined by ARC ground personnel to be potentially harmful to crops. The results and analysis of the operation are discussed in the ARC's final report on weather modification which is being prepared for the Minister.

Weather modification research by the ARC started in 1969 with cloud seeding experiments using silver iodide. In 1973 the Alberta Weather Modification Advisory Board was established and the ARC began a detailed hail suppression research program. This research was funded from 1973 to 1985. During this period, the ARC collected huge amounts of data on hail storms, including radar reflectivity, hail swaths, hail stone sizes, reaction of clouds to seeding, and numerous other complex measurements taken from the ground as well as from aircraft. Much of these data will be analyzed and interpreted in the ARC final report.

For the purpose of this study, a detailed breakdown of the costs involved with an operational seeding program was required. The following section outlines the approach taken in analyzing the costs of a weather modification system for Alberta.

A Proposed Weather Modification System for Alberta

The objective of this section is to design (and cost) a weather modification system for Alberta. Estimates of infrastructure and operating costs were derived from the ARC operational hail seeding program. The system was expanded to cover a much larger area than the operational seeding program; seeding for hail and drought were considered. Areas which were not considered high risk (hail/drought) were excluded.

Staff from the ARC who were involved in the contracting for the past operational seeding designed a weather modification system which could potentially cover all required areas of the province. The major cost components of the system are as follows:

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[1] Information obtained from the "Proceedings of Eleventh Annual Meeting of the North American Interstate Weather Modification Council", August 1984, Red Deer, Canada.

i) Capital for infrastructure:

- radar facilities
- aircraft
- buildings and ground equipment (including vehicles)
- computer facilities required
- program administration

ii) Labor

- full-time professional staff requirements
- part-time professional (summer)
- full-time wage positions
- part-time wage positions
- pilots & other highly specialized positions

iii) Materials and services:

- cloud seeding material
- fuel & repairs/maintenance (aircraft)
- insurance
- program (adverse effects)
- aircraft & pilots/researchers

A project life was chosen for economic analysis so that there was sufficient time for payback of major capital investment. The length of time required to pay back the major investment was, of course, related to expected benefits or revenues generated from the investment. Since the benefits of weather modification could not be precisely measured, several simplifying assumptions were made. A break-even approach was used to calculate the benefits needed for payback. Total capital and annual operating costs were derived for a system that was deemed feasible for Alberta.

In earlier sections of the report, the losses of major crops from hail and drought were calculated. The total annual cost of the proposed weather modification system, as a percentage of total losses from hail and drought, are presented below. This estimate gives a good benchmark for required performance of the weather modification system. It allows one to examine the extent to which weather modification must be effective to recapture the investment and operating costs. A matrix of total crop loss relative to weather modification costs is presented to allow for some sensitivity analysis.

ARC's experience with drought suppression is very limited. No data are available on drought suppression in Alberta. A straight percentage of total loss due to drought could be used. Timing and amount of water required to increase or sustain yield (taking into consideration evaporation, evapotranspiration, etc.) are critical for a successful drought suppression program. Considering the area to be covered, and the difficulty with timing and delivering the needed amounts of rain, the accuracy in estimating both the costs and the benefits of this program are open to question. However, by estimating the extent of the annual crop loss, policy makers can get an idea of the potential benefits to be

derived from public investment in rain, snowfall enhancement, and water conservation.

Capital and Operating Costs

The weather modification system was designed using the Red Deer site as a prototype. Five sites were chosen to offer complete coverage of the province (see Figure 2). Capital and operating costs were derived using past experience and informed estimates. Contract seeding costs from past operational seeding were used for the proposed radar sites.[1]

A summary of the capital and operating costs of five radar sites including cloud seeding with a total of 18 aircraft are given in Table 6.

TABLE 6: SUMMARY OF CAPITAL AND OPERATING COSTS

Sites	Capital	Manpower & Operating	Airseeding Contract	Total Annual Operating
		- - - - dollars - - - -		
New Sites (4)	3,972,700	625,600	2,652,000	3,277,600
Red Deer Site	-	156,400	663,000	819,400
Red Deer Control	-	311,500	n/a	311,500
TOTAL	3,972,700	1,093,500	3,315,000	4,408,500

All of the capital costs except land are replaced within 5 to 20 years. Computer equipment is replaced every 5 years, radar equipment every 15 years, and buildings every 20 years. The total discounted[2] capital costs, including replacement, over the 20 years is $5.4 million. Total discounted operating costs for the five sites and the Red Deer administrative office is $50.7 million (or $4.1 million per year). Therefore, the total discounted cost of the system over the 20 year period is $56.2 million ($4.5 million annually). Appendix A has a detailed breakdown of costs.

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[1] Jim Renick and Fritz Kamprath, from ARC, provided the cost estimates.

[2] Discounting is done at 5 per cent (social discount rate). Sensitivity analysis used 3 per cent and 7 per cent. See Appendix C.

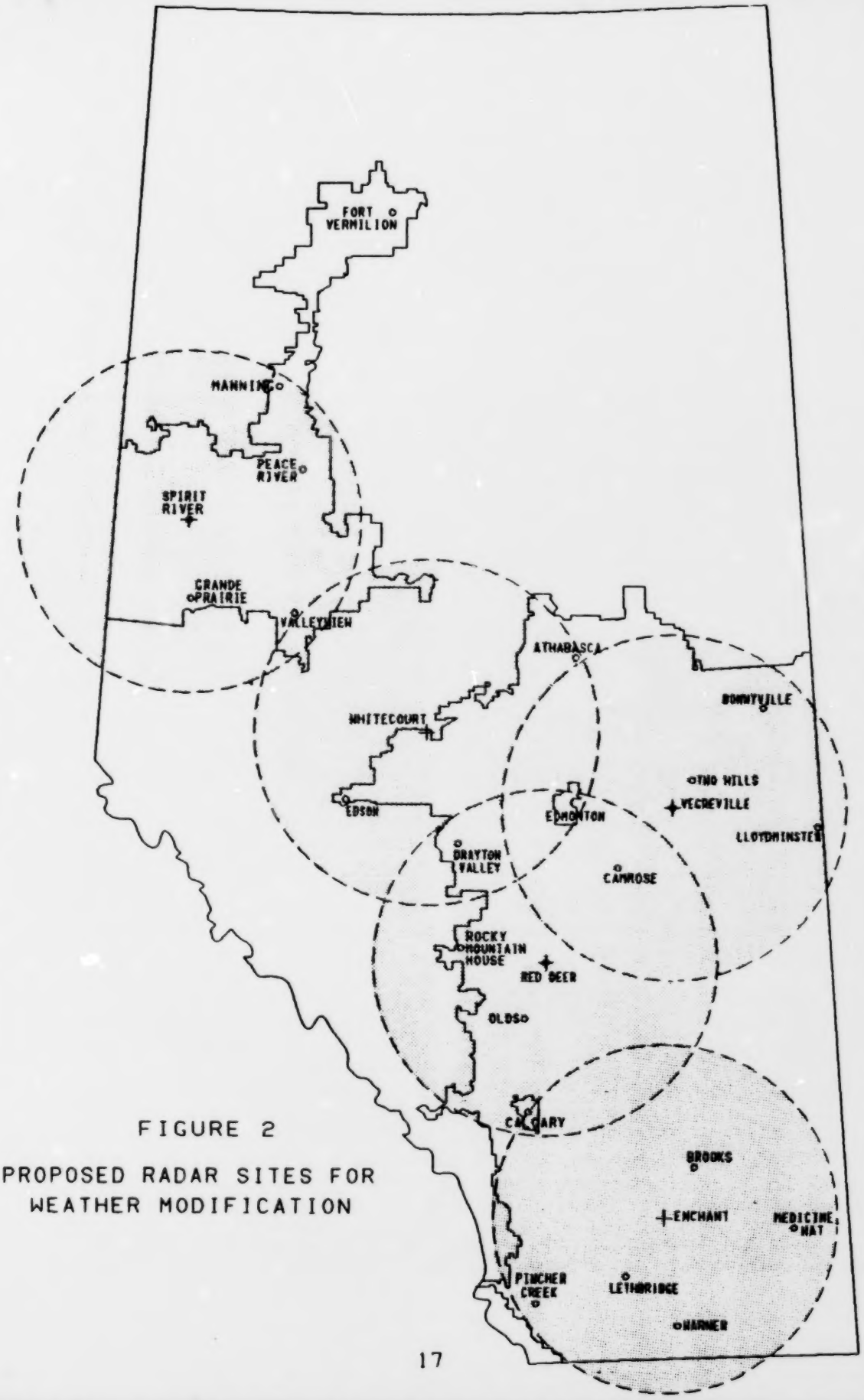

FIGURE 2

PROPOSED RADAR SITES FOR WEATHER MODIFICATION

VII. ECONOMIC ANALYSIS: DIRECT AND SECONDARY

Hail

The economic analysis demonstrates the level of crop loss recovery which is necessary for the weather modification system to break even. Only the direct on-farm benefits and costs of hail damage are evaluated and compared to the weather modification system costs. These losses have been estimated in previous sections of the report and will now be analyzed in the 20 year project framework. All benefits and costs are in constant dollars (1985). The discount rate chosen was a social discount rate of 5 per cent, with sensitivity analysis at 3 per cent and 7 per cent.

Secondary benefits are included in the sensitivity analysis to show the impact of indirect benefits of hail suppression. These indirect (or secondary) impacts include trucking and rail transport benefits, processing (canola crushing), employment and value-added through livestock. Other impacts include the sale of weather modification expertise and technology to other countries, and the availability of meteorological data for other uses, eg., weather forecasting. These impacts are difficult to measure. However, branch staff experienced with secondary impact analysis feel that value-added of 15 to 35 per cent is reasonable. Therefore, sensitivity analysis was done at 15, 25 and 35 per cent.

Willingness to Pay (WTP)

The WTP approach uses premiums paid and administration costs as a proxy for the total willingness to pay for protection against the risk of hail (in dollar terms). In Section IV, the results of this analysis indicated a total annual willingness to pay value of $75.2 million. This value discounts to $865.1 million over the 20 year project life[1]. In Section VI, the total discounted cost of the weather modification system was $56.2 million. If the system is to break even, crop losses would have to be reduced by $56.2 million over the 20 year project. This represents 6.5 per cent of accumulated premiums and administration costs. Alternatively, benefits equivalent to 6.5 per cent of premiums and administration costs are sufficient to pay for the total system cost, i.e. $4.5 million per year.

If secondary benefits are included in the analysis at 15, 25 and 35 per cent, a smaller percentage reduction in crop losses would be needed for the system to break even. At the three levels of secondary benefits, 15, 25 and 35 per cent, reduction in annual crop losses of $3.9, $3.6 and $3.3 million, respectively, would be needed for the system to break even.

The effect of increasing system costs and changing the discount rate are given in Appendix B.

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[1] Since all infra-structure is assumed to be in place in year one, loss and premium data are reported for years 2 through 20.

Total Adjusted Loss Payout by AHCIC

Table 2 shows that the total average annual adjusted loss payout due to hail is $93 million. The total discounted hail loss over the 20 year project ($93 million from year 2 to 20) is $1.07 billion. The economic analysis reveals that under the base case 5.25 per cent of total discounted losses need to be prevented so that the weather modification system can break even. It is interesting to note that if annual losses are $93 million and weather modification is able to prevent 10 per cent of total losses (or damage), the net present value will be $51 million. If the operating and capital costs are underestimated by as much as 20 per cent, the break-even damage prevention required would rise to only 6.3 per cent.

When secondary benefits are included in the analysis at 15, 25 and 35 per cent, the requisite percentage reduction in crop losses declines to 4.6 per cent, 4.2 per cent and 3.9 per cent, respectively. Other sensitivity analysis (increases in system costs) can be found in Appendix B.

AHCIC Loss-to-Risk and Total Crop Production

As explained in Section IV, this analysis employs statistical information on total crop production value and historical loss-to-risk ratios. The 1971-85 average annual value of crops produced in Alberta was $3.19 billion (in 1985 dollars). The average loss-to-risk ratio for the same period was 4.22 per cent, implying an average annual crop loss of $134.4 million due to hail. This discounts to $1.55 billion over the 20 year project life, resulting in a percentage loss recovery of only 3.6 per cent. With secondary benefits included, loss recovery decreases to 3.7 per cent, 2.9 per cent and 2.7 per cent for secondary benefits of 15, 25 and 35 per cent, respectively. It should be noted that this estimate represents an upper limit to hail damage in the province, and thus provides the lowest needed loss recovery of all alternatives considered, i.e., the greater the damage the lower will be the amount of damage reduction needed to pay for the system.

AHCIC Loss-to-Risk and Total Risk

Method D showed that the average annual risk written between 1976 and 1985 was $873.7 million (in 1985 dollars). Discounted over 20 years, this value amounts to $10.05 billion. The 1971-85 average loss-to-risk ratio was 4.22 per cent, resulting in an average annual loss of $58.8 million after adjusting for coverage levels (62.7 per cent). This annual adjusted loss of $58.8 million amounts to $676.5 million when discounted over the 20 year project. The system costs of $56.2 million (over 20 years) represented 8.3 per cent of the estimated crop loss. This represents the highest required loss recovery percentage of all methods used to estimate hail damage. None of the sensitivity analysis drove the required loss recovery percentage over 10 per cent; a 20 per cent increase of system costs forced the loss recovery to almost 10.0 per cent.

The ARC has done experimentation with cloud seeding for rain enhancement. Unlike hail, there was no operational seeding for rain enhancement. As a result, estimation of additional costs above and beyond the operating costs of the hail weather modification system are difficult to predict. The actual success rate of rain enhancement for crop production in Alberta is also not known. Therefore, the effectiveness of rain enhancement in Alberta is difficult to estimate. Following are the major reasons:

- No operational program has been in place to date.
- The timeliness of rainfall is crucial, and the ability of weather modification to deliver rainfall during these crucial times has not been documented.
- The extent to which weather modification can reduce the effects of drought are also not clear; if there are no clouds there can be no rain enhancement.
- The unit increase in rainfall required to create a bushel/acre increase in crop production is variable. Because of variables such as timing and evaporation, a one per cent increase in rainfall may not necessarily generate a one per cent increase in crop production.
- The minimum amount of a single rainfall which is required for an increase in crop production is not known.

However, rain enhancement can serve to increase overall average production moving it closer to the optimum level as described in Section V.

TABLE 7: LOSS RECOVERY AND DISCOUNTED (20 YEAR) CROP PRODUCTION VALUES

Success Rate %*		0.1%	0.5%	1.0%	2.0%	5.0%	10.0%	100.0%
		----------	----------	----------	$ million	----------	----------	----------
	0.1	0.20	0.98	1.97	3.93	9.83	19.66	196.63
Efficiency of	0.2	0.39	1.97	3.93	7.87	19.66	39.33	393.27
	0.3	0.59	2.95	5.90	11.80	29.49	58.99	589.90
Rain	0.4	0.79	3.93	7.87	15.73	39.33	78.65	786.53
	0.5	0.98	4.92	9.83	19.66	49.16	98.32	983.16
Enhancement	0.6	1.18	5.90	11.80	23.60	58.99	117.98	1179.80
	0.7	1.38	6.88	13.76	27.53	68.82	137.64	1376.43
	0.8	1.57	7.87	15.73	31.46	78.65	157.31	1573.06
	0.9	1.77	8.85	17.70	35.39	88.48	176.97	1769.69
	1.0	1.97	9.83	19.66	39.33	98.32	196.63	1966.33

* An efficiency of 1.0 and loss recovery percentage of 100 per cent results in the full $1,590 million ($1.59 billion) in crop production values to be recovered.

Table 7 shows the total discounted crop production values for various levels of system efficiencies and loss recovery rates (these are not annual cash flows). Table 8 converts Table 7 to annual equivalent cash flows. If rain enhancement has a 0.5 efficiency rating (an increase in rainfall of 10 per cent will yield a crop production increase of 5 per cent) and the success rate of generating rainfall is 5 per cent, then the corresponding annual crop benefit is $3.95 million.[1] Also notice that the total annualized crop production deficit (grains and hay) is $157.8 million. This could be recovered only if the system is 100% successful and the efficiency is 1.0.

TABLE 8: LOSS RECOVERY AND ANNUAL CROP PRODUCTION BENEFITS*

Success Rate %		0.1%	0.5%	1.0%	2.0%	5.0%	10.0%	100.0%
					$ '000			
	0.1	16	79	158	316	789	1,578	15,778
Efficiency of	0.2	32	158	316	631	1,578	3,156	31,557
	0.3	47	237	473	947	1,367	4,734	47,335
Rain	0.4	63	316	631	1,262	3,156	6,311	63,113
	0.5	79	394	789	1,578	3,945	7,889	78,892
Enhancement	0.6	95	473	947	1,893	4,734	9,367	94,670
	0.7	110	552	1,104	2,209	5,522	11,045	110,448
	0.8	126	631	1,262	2,525	6,331	12,623	126,227
	0.9	142	710	1,420	2,840	7,100	14,201	142,005
	1.0	158	789	1,578	3,156	7,889	15,778	157,783

* Including wheat, barley, oats, canola and hay.

To date operational cost estimates of a rain enhancement system are not available. The capital infrastructure costs designed for the hail suppression program (Section VI) was assumed to cover both a hail and rain cloud seeding program. Time did not permit the documentation of the number of aircraft required, and additional cost of materials and manpower for rain enhancement.

Some additional benefits which were not quantified here include the following:

- Secondary benefits from increased crop production.
- Net farm income increases of farmers affected by weather modification.
- Benefits from income stability.
- Benefits from increased pasture production (livestock industry).
- Employment of labor and resources (operational and research related) for the weather modification system.

[1] This is a purely hypothetical example.

These benefits listed above should weigh heavily in the "economic" decision of weather modification. Further detailed studies could derive the approximate dollar value of these benefits. However, within the scope of this study, it is easy to see that benefits do exist. Again, any realization of the direct or indirect benefits discussed, strengthens and supports the argument for a weather modification system.

VIII. SUMMARY AND CONCLUSION

This study has attempted to estimate the loss in crop production due to hail storms and lack of sufficient moisture during the growing season. Several methods were used to estimate hail damage. Using mainly AHCIC data, the results indicated an average annual loss to hail ranging from $59 million to $134 million, depending on the method of analysis. These losses were then discounted over a 20 year period to facilitate evaluation of a suitable weather modification system for Alberta.

The proposed provincial weather modification system was developed in consultation with ARC personnel drawing from the experience of the Red Deer operation. The capital infrastructure costs were estimated at $4 million, and annual operating costs at $4.41 million. Discounted over 20 years, these expenditures translate into an average annual cost of $4.5 million.

We do not know precisely how much hail damage can be prevented by, say, "one unit of hail suppression". Such answers will probably come from the ARC report. Consequently, the analysis was done in terms of cost recovery, which does provide a useful perspective for project evaluation. The hail analysis summarized in Table 8 shows that a reduction in annual damage of less than 10 per cent is more than sufficient to recapture the annual cost of a provincial hail suppression system. When secondary benefits are considered, the loss recovery rate ranged between 3.2 and 7.2 per cent, depending on the method of analysis.

For a more detailed breakdown of the sensitivity analysis refer to Appendix B.

Due to data limitations and time constraints, the drought analysis was somewhat more cursory. Annual losses due to drought were estimated at $157.8 million. We do not know how much additional output would be forthcoming from an extra inch of rainfall during the growing season. Yet, it is fair to say that rain enhancement will have a substantial positive impact on the overall feasibility of the weather modification project.

The study did not consider spin-off benefits of hail damage reduction in populated areas and aspects of litigation associated with operating a weather modification system. Litigation costs remain a possibility, although no lawsuits have been taken to completion.

Benefits and costs of snowfall enhancement and management were beyond the scope of this report. Such research aimed at improving crop and livestock production should receive serious consideration, as well as a more definitive examination of the economics of persistent drought in some parts of the province.

In conclusion, given the limited data available for estimating annual drought losses, the authors are of the view that the weather modification system should be justified on the basis of hail suppression. The analysis clearly shows that the proposed weather modification system pays for itself with less than 10 per cent reduction in hail damage. Rain enhancement can help to increase overall crop production and reduce the severity of drought; benefits resulting from enhanced rainfall, combined with the secondary benefits from hail suppression, will obviously add to the rationale for a weather modification system.

APPENDIX A

COST OF WEATHER MODIFICATION SYSTEM

COST ESTIMATE, RADAR SITE
(BASED ON 5 SITES)

		Cost/Site	Years
1.	LAND AND BUILDINGS		
i)	Land	$ 20,000	
ii)	Buildings (20' X 40')	30,000	20
iii)	Building foundation and site preparation	25,000	50
iv)	Building water and sewage	25,000	20
v)	Power installation	25,000	
	TOTAL Land and Buildings	$125,000	
2.	EQUIPMENT COST, INSTALLATION, PREPARATION		
i)	Radar Equipment*		
	-computers	$100,000	5
	-base radar	243,000	15
	-controller station	125,000	15
	-tracking radar	66,500	15
	-radio system	30,000	15
	-F.O.B. @ 15%	84,675	
ii)	Radiosonde (Vauxhall, Spirit River, Red Deer Two Hills)	75,000	10
iii)	Tower Installation		
	-engineering consulting fees	8,000	
	-foundation	10,000	
	-erection costs	25,000	
	-power	5,000	
	-F.O.B. @ 15%	6,000	
iv)	Capital Costs for Air Seeding		
	a) Seeding equipment @ $25,000/plane and 3.6 planes/site	90,000	10
	TOTAL Equipment and Installation Costs	$868,175	

* Red Deer site will be replaced in 3 years, and every 15 years after that.

3. OPERATING COSTS: RADAR SITE		Cost/Site
i)	Materials (tapes, other supplies, housekeeping, etc)	$ 30,000
ii)	Utilities	
	-telephone & Altel data line $1500/mo. @ 3 mths.	4,500
	-15,000 W/Hr (electricity) 24 hrs/day @ 3 mths.	1,800
iii)	Salaries	
	-1/2 tech/year/site @ $30,000/year	15,000
	-2 techs, 4 months @ $20,000/year	13,200
	-1 Radiosonde tech, 3 months @ $20,000/year	3,000
iv)	Supplies for Radiosonde $250/day for 3 months	13,500
TOTAL Annual Operating Costs		$ 81,000

4. MAINTENANCE		
i)	Computers Contract agreement $500/day @ 1 day/week @ 3 mths	$ 6,000
ii)	Buildings 20' X 40' = 800 sq. ft. @ $3/sq.ft. = $2400/year	2,400
iii)	Site Grounds maintenance	1,000
iv)	Radar 65,000/3 month season	65,000
v)	Radio	1,000
TOTAL Annual Maintenance Costs		$ 75,400

5. AIR SEEDING CONTRACT		
i)	Aircraft and crew (2 people) @ $1,000/day (2.4 hrs fly time allowance per day) 18 total aircraft @ 5 sites, cost per site	$324,000
ii)	Air traffic controllers $6,500/month/controller; 3 controllers/site	58,500
iii)	Fuel $15,000/plane/season (3 months) Average of 3.6 planes/site (5 sites)	54,000
iv	Management fee	10,000
iv)	Seeding equipment technician (contracted) 1/site @ $5,500/month for 3 months	16,500
v)	Cloud seeding material $200,000/site	200,000
TOTAL Annual cloud seeding contract		$663,000

6. RED DEER: CONTROL AND ADMINISTRATION

		Red Deer
A.	Operating Costs	
i)	Forecasting operation to estimate aircraft allocation/weather patterns	$ 30,000
ii)	Project manager for all sites, located at Red Deer	50,000
iii)	Forecaster 1 1/2 time @ $6,500/month for 4 months	39,000
iv)	Administration & Management	150,000
v)	Two vehicles for controlling site (leased)	10,000
vi)	Aurora telephone system	8,500
vii)	Dedicated data lines to 4 sites $2000/month/site, 4 sites	24,000
TOTAL cost for central office and administration		$311,500

SUMMARY OF CAPITAL AND OPERATING COSTS

	Capital	Manpower & Operating	Airseeding Contract	Total Annual Operating
		-- dollars --		
New Sites (4)	3,972,700	625,600	2,652,000	3,277,600
Red Deer Site	-	156,400	663,000	819,400
Red Deer Control	-	311,500	n/a	311,500
TOTAL	3,972,700	1,093,500	3,315,000	4,408,500

APPENDIX B

SENSITIVITY ANALYSIS

APPENDIX B

SENSITIVITY ANALYSIS - HAIL DAMAGE

		Method of Analysis			
		A	B	C	D
		- - - million $ - - -			
1.	Discounted Value of Crop Loss*	865.1	1070.0	1550.0	676.5
	Discounted Annual Crop Loss*	75.2	92.9	134.4	58.8
	Discounted Weather Mod. System Cost	56.2	56.2	56.2	56.2
	Discounted Annual System Cost	4.5	4.5	4.5	4.5
	Annual Loss				
2.	Loss Recovery % for Breakeven	- - - per cent - - -			
	Base case	6.49	5.25	3.63	8.30
	3% Discount Rate	6.38	5.16	3.57	8.16
	7% Discount Rate	6.61	5.35	3.70	8.45
	10% Increase in System Costs	7.14	5.77	3.99	9.13
	20% Increase in System Costs	7.79	5.77	3.99	9.13
	Secondary Benefits 15%	5.65	4.56	3.16	7.22
	25%	5.19	4.20	2.90	6.64
	35%	4.81	3.89	2.69	6.15
3.	NPV at 10% Loss Recovery	- - - million $ - - -			
	Base Case	30.3	50.8	98.5	11.5
	3% Discount Rate	37.8	62.6	120.2	15.0
	7% Discount Rate	24.6	41.8	81.8	8.8
	10% Increase in System Costs	24.7	45.2	92.9	5.9
	20% Increase in System Costs	19.1	39.6	87.3	0.3
	Secondary Benefits 15%	43.3	66.9	121.7	21.7
	25%	52.0	77.6	137.2	28.4
	35%	60.6	88.3	152.7	35.2
4.	Benefit/Cost Ratio at 10% Loss Recovery	- - - ratio - - -			
	Base Case	1.54	1.91	2.75	1.20
	3% Discount Rate	1.57	1.94	2.80	1.23
	7% Discount Rate	1.51	1.87	2.70	1.18
	10% Increase in System Costs	1.40	1.73	2.50	1.10
	20% Increase in System Costs	1.28	1.59	2.29	1.00
	Secondary Benefits 15%	1.77	2.19	3.17	1.39
	25%	1.93	2.38	3.44	1.51
	35%	2.08	2.57	3.72	1.63

* These are the discounted total crop losses due to hail without any loss recovery from the weather modification system.

20 YEAR PROJECT FLOWS

iii. LOSSES AND PREMIUMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
(A) PREMIUMS (AHCIC)	0	64,368	64,368	64,368	64,368	64,368	64,368	64,368	64,368	64,368	64,368	64,368	64,368	64,368	64,368	64,368	64,368	64,368	64,368	64,368
PREMIUMS (PRIVATE)	0	10,790	10,790	10,790	10,790	10,790	10,790	10,790	10,790	10,790	10,790	10,790	10,790	10,790	10,790	10,790	10,790	10,790	10,790	10,790
(B) LOSSES (AHCIC)	0	49,760	49,760	49,760	49,760	49,760	49,760	49,760	49,760	49,760	49,760	49,760	49,760	49,760	49,760	49,760	49,760	49,760	49,760	49,760
LOSSES (PRIVATE)	0	8,534	8,534	8,534	8,534	8,534	8,534	8,534	8,534	8,534	8,534	8,534	8,534	8,534	8,534	8,534	8,534	8,534	8,534	8,534
ADJ LOSSES (62.7%)	0	92,972	92,972	92,972	92,972	92,972	92,972	92,972	92,972	92,972	92,972	92,972	92,972	92,972	92,972	92,972	92,972	92,972	92,972	92,972
ACRES (AHCIC)	0	10,213	10,213	10,213	10,213	10,213	10,213	10,213	10,213	10,213	10,213	10,213	10,213	10,213	10,213	10,213	10,213	10,213	10,213	10,213
ACRES (PRIVATE,EST)	0	1,640	1,640	1,640	1,640	1,640	1,640	1,640	1,640	1,640	1,640	1,640	1,640	1,640	1,640	1,640	1,640	1,640	1,640	1,640

vii. ECONOMIC ANALYSIS

SENSITIVITY ANALYSIS--->BASE CASE

DISCOUNT RATE-----> 5.0%
SECONDARY BENEFITS>1.00

	(A) PREMIUMS 1.0%	(A) PREMIUMS 5.0%	(A) PREMIUMS 6.49%	(A) PREMIUMS 10.0%	(A) PREMIUMS 15.0%	(B) LOSSES 1.0%	(B) LOSSES 5.0%	(B) LOSSES 5.25%	(B) LOSSES 10.0%	(B) LOSSES 15.0%
	('000)					('000)				
(1) DISCOUNTED BENEFITS--------->	8,651	43,253	56,168	86,506	129,759	10,701	53,505	56,168	107,010	160,514
(2) DISCOUNTED CAPITAL COSTS---->	5,427	5,427	5,427	5,427	5,427	5,427	5,427	5,427	5,427	5,427
(3) DISCOUNTED OPERATING COSTS-->	50,741	50,741	50,741	50,741	50,741	50,741	50,741	50,741	50,741	50,741
TOTAL------->	56,168	56,168	56,168	56,168	56,168	56,168	56,168	56,168	56,168	56,168
(4) NET PRESENT VALUE---------->(47,518)		(12,916)	0	30,337	73,590	(45,468)	(2,664)	0	50,841	104,346
(5) BENEFIT-COST RATIO---------->	0.15	0.77	1.00	1.54	2.31	0.19	0.95	1.00	1.91	2.86
(6) ANNUAL EQUIVALENT CASH FLOW->	NA	NA	NA	2,434	5,905	NA	NA	NA	4,080	8,373
(7) LOSS RECOVERY REQUIRED------>	0.81%	4.04%	5.25%	8.08%	12.13%	NA	NA	NA	NA	NA

A. Willingness to Pay (WTP): the total amount farmers and society (through government) are willing pay for protection against the risk of hail via hail insurance.
B. Total Adjusted Loss Payouts by AHCIC for insurance claims for hail damage.
C. AHCIC Loss-to-Risk applied to total value of crop production.
D. AHCIC Loss-to-Risk applied to total risk written by AHCIC.

20 YEAR PROJECT FLOWS

iii. LOSS TO RISK (C & D)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
(C) L/R I TOTAL CROP $																				
(1) 1971-85 AVE L/R RATIO	0	4.22%	4.22%	4.22%	4.22%	4.22%	4.22%	4.22%	4.22%	4.22%	4.22%	4.22%	4.22%	4.22%	4.22%	4.22%	4.22%	4.22%	4.22%	4.22%
(2) TOT $ FIELD CROPS (M)	0	3185.04	3185.04	3185.04	3185.04	3185.04	3185.04	3185.04	3185.04	3185.04	3185.04	3185.04	3185.04	3185.04	3185.04	3185.04	3185.04	3185.04	3185.04	3185.04
(3) L/R I TOTAL $ (M)	0	134.39	134.39	134.39	134.39	134.39	134.39	134.39	134.39	134.39	134.39	134.39	134.39	134.39	134.39	134.39	134.39	134.39	134.39	134.39
(D) L/R I RISK WRITTEN																				
(4) AVE RISK WRITTEN (M)	0	873.71	873.71	873.71	873.71	873.71	873.71	873.71	873.71	873.71	873.71	873.71	873.71	873.71	873.71	873.71	873.71	873.71	873.71	873.71
(5) L/R I RISK WRITTEN(M)	0	36.87	36.87	36.87	36.87	36.87	36.87	36.87	36.87	36.87	36.87	36.87	36.87	36.87	36.87	36.87	36.87	36.87	36.87	36.87
(6) ADJ LOSSES (62.7%)	0	58.80	58.80	58.80	58.80	58.80	58.80	58.80	58.80	58.80	58.80	58.80	58.80	58.80	58.80	58.80	58.80	58.80	58.80	58.80

iv. LOSS RECOVERY (000)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
BREAKEVEN (C)----> 3.6%	0	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880
10.0%	0	13,439	13,439	13,439	13,439	13,439	13,439	13,439	13,439	13,439	13,439	13,439	13,439	13,439	13,439	13,439	13,439	13,439	13,439	13,439
BREAKEVEN (D)----> 8.3%	0	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880	4,880
10.0%	0	5,880	5,880	5,880	5,880	5,880	5,880	5,880	5,880	5,880	5,880	5,880	5,880	5,880	5,880	5,880	5,880	5,880	5,880	5,880
0.0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

vi. ECONOMIC ANALYSIS

SENSITIVITY ANALYSIS--> BASE CASE
RUN DATE----------> 22-Jul-86

DISCOUNT RATE-----> 5.0%
SECONDARY BENEFITS>1.00

	(C) --TOTAL VALUE-- 3.63%	(C) --TOTAL VALUE-- 10.0%	(D) --RISK X L/R-- 8.30%	(D) --RISK X L/R-- 10.0%
	('000)			
(1) DISCOUNTED BENEFITS--------->	56,168	154,686	56,168	67,677
(2) DISCOUNTED CAPITAL COSTS---->	5,427	5,427	5,427	5,427
(3) DISCOUNTED OPERATING COSTS-->	50,741	50,741	50,741	50,741
TOTAL (pv) ALL COSTS-------->	56,168	56,168	56,168	56,168
AECF TOTAL COSTS------------>	4,507	4,507	4,507	4,507
(4) NET PRESENT VALUE----------->	0	98,518	0	11,508
(5) BENEFIT-COST RATIO---------->	1.00	2.75	1.00	1.20
(6) ANNUAL EQUIVALENT CASH FLOW->	NA	7,905	0	923

A. Willingness to Pay (WTP): the total amount farmers and society (through government) are willing to pay for protection against the risk of hail via hail insurance.
B. Total Adjusted Loss Payouts by AHCIC for insurance claims for hail damage.
C. AHCIC Loss-to-Risk applied to total value of crop production.
D. AHCIC Loss-to-Risk applied to total risk written by AHCIC.

APPENDIX C

YIELD DATA

FOR MAJOR CROPS

BY CENSUS DIVISION

APPENDIX C

YIELD DATA FOR WHEAT.

YIELD (bu./ac.)

C.D.	73	74	75	76	77	78	79	80	81	82	83	84	85
1	12.0	15.7	27.7	28.5	16.1	28.8	20.4	26.7	31.0	28.7	29.5	13.7	15.8
2	13.7	18.0	33.6	30.4	17.4	31.1	22.2	30.7	35.4	27.5	25.1	11.9	26.0
3	22.9	26.2	34.4	26.1	18.4	34.4	22.3	31.1	36.4	27.7	23.9	7.5	12.8
4	29.8	23.2	23.4	26.4	13.1	17.7	22.5	22.2	23.2	26.8	27.3	15.7	15.2
5	33.1	30.7	33.3	32.0	21.3	33.3	27.6	33.2	39.1	35.8	33.6	21.7	22.0
6&9	35.7	35.2	31.1	31.7	31.6	40.3	33.3	38.5	44.1	38.9	37.4	18.2	20.9
7	32.8	24.5	28.6	34.4	24.6	21.2	31.7	35.6	25.3	33.5	30.2	24.9	25.7
8	40.1	34.6	32.5	40.9	37.0	37.9	36.7	44.2	42.9	41.2	44.4	36.3	30.3
10	32.8	25.2	27.6	36.3	34.2	26.7	34.8	37.0	26.9	33.9	27.9	32.9	29.9
11	28.4	28.5	32.7	39.8	36.4	32.5	39.7	41.9	39.2	34.0	29.6	40.6	42.7
12	32.3	19.4	26.8	34.6	28.2	28.7	31.4	32.6	32.6	24.7	30.5	30.5	29.9
*13	18.4	25.3	30.0	35.9	31.8	31.9	34.5	36.7	42.4	29.0	33.7	40.1	33.9
*14		17.5	29.9	34.0	21.2	35.6	28.6	25.3	34.5	26.3	12.7	26.7	33.9
15	19.3	21.0	32.4	37.3	27.6	27.2	36.9	32.2	30.3	15.9	36.5	29.4	21.6
WEIGHTED	25.8	23.9	30.3	32.5	23.3	28.3	28.8	32.4	32.0	29.6	30.4	24.8	22.9

YIELD DATA FOR OATS.

YIELD (bu./ac.)

C.D.	73	74	75	76	77	78	79	80	81	82	83	84	85
1		34.9	47.5	52.1	24.6	48.1	34.1	41.1	52.8	51.9	56.7	14.6	29.4
2	31.6	45.8	62.1	48.8	30.6	56.5	40.9	51.3	58.2	37.2	38.4	9.6	56.6
3	43.2	47.4	56.5	49.3	22.0	61.8	35.5	52.6	65.3	44.0	33.3	7.1	17.1
4	35.5	29.3	31.0	31.4	13.9	25.1	37.1	38.6	32.4	44.5	35.7	15.2	29.4
5	64.2	54.0	54.0	52.1	34.8	52.5	50.3	60.7	68.3	63.9	59.3	27.6	38.8
6&9	70.5	63.9	48.6	57.6	63.7	70.9	61.7	70.1	82.7	78.7	76.6	36.2	41.1
7	55.2	36.6	40.4	45.6	33.7	31.4	50.7	56.0	35.5	58.6	48.8	26.1	49.8
8	62.7	57.4	52.8	60.9	75.2	62.2	66.6	65.1	74.8	64.8	71.1	56.3	55.6
10	56.8	35.3	39.8	46.3	60.9	34.7	59.7	50.1	48.4	63.5	37.5	42.1	50.1
11	61.4	48.1	58.8	62.9	66.6	47.7	69.2	58.7	69.1	65.4	49.6	59.5	67.9
12	57.5	31.9	44.9	51.7	57.3	48.1	59.6	52.7	53.5	58.0	55.7	39.4	55.0
*13	40.2	43.1	56.3	64.2	63.5	56.6	66.7	66.3	74.3	60.5	60.6	65.3	67.3
*14	60.0	35.8	55.8	63.8	41.4	55.1	68.0	51.7	57.6	55.3	48.1	33.9	67.3
15	33.7	39.3	50.8	63.6	48.7	48.7	64.3	58.0	42.2	22.3	62.5	50.0	42.1
WEIGHTED	53.2	41.0	47.7	53.3	52.5	45.4	58.8	56.1	55.5	57.5	52.0	42.0	52.4

APPENDIX C

YIELD DATA FOR CANOLA.

C.D.	YIELD (bu./ac.)												
	73	74	75	76	77	78	79	80	81	82	83	84	85
1	6.3	4.9	13.3	10.0	18.0	20.0	13.9	15.7	25.0	14.4	19.9	7.7	17.6
2	7.6	11.7	14.0	22.4	12.3	22.5	16.1	27.7	26.2	20.3	17.7	7.3	18.5
3	14.3	12.6	10.3	27.1	18.3	22.6	14.3	23.1	21.9	13.5	11.9	5.8	12.5
4		17.3	16.0	17.3	14.4	9.9	16.3	16.8	21.1	14.7	14.8	11.8	17.6
5	21.7	23.1	20.7	23.4	20.8	24.5	21.4	25.5	30.2	26.2	22.4	13.6	18.5
6&9	22.3	25.0	21.2	23.9	25.7	27.1	21.8	20.8	28.9	26.5	23.3	13.0	12.5
7	20.2	17.8	18.0	24.9	25.2	16.0	21.8	26.7	23.5	24.5	18.9	18.4	20.0
8	22.7	25.0	23.7	26.2	28.6	26.7	25.1	21.7	26.9	20.4	22.9	25.2	22.0
10	19.3	15.6	19.0	23.2	26.8	20.4	18.2	26.3	22.8	21.9	15.2	22.5	20.5
11	16.8	14.5	18.8	22.9	23.4	23.0	16.3	20.2	24.4	20.7	12.4	26.5	22.0
12	20.8	10.3	12.2	18.5	21.5	17.4	14.5	21.9	21.7	18.0	15.4	22.1	22.9
*13	15.0	12.6	12.6	17.1	17.8	18.0	11.6	17.8	21.3	15.4	12.6	23.7	22.9
*14		13.9	14.5	17.8	5.8	15.5	6.0	6.0	10.3	14.2	3.0	23.0	22.9
15	12.9	13.0	17.1	15.2	14.8	17.1	12.9	21.4	15.5	9.2	14.6	15.4	15.2
WEIGHTED	17.3	15.9	17.7	21.2	21.4	19.7	17.2	23.3	21.9	18.4	16.3	18.8	18.9

YIELD DATA FOR BARLEY.

C.D.	YIELD (bu./ac.)												
	73	74	75	76	77	78	79	80	81	82	83	84	85
1	12.7	21.7	40.9	43.9	23.5	46.1	30.3	38.3	45.4	38.2	40.7	12.1	30.5
2	21.5	32.3	49.1	43.4	29.9	44.6	35.3	49.8	56.0	41.4	40.1	12.0	47.9
3	31.9	46.3	50.0	43.8	33.7	52.4	40.5	54.1	53.5	46.0	42.1	8.6	14.9
4	49.6	29.8	27.5	33.8	18.2	25.0	35.8	35.9	36.4	47.5	36.4	19.3	25.4
5	50.5	47.6	46.8	43.0	34.3	51.6	43.6	52.1	59.6	56.2	51.8	24.8	33.2
6&9	50.9	49.8	40.9	43.3	55.0	58.2	51.3	53.2	61.9	58.6	59.7	30.1	30.3
7	42.6	31.8	36.4	42.9	40.4	34.1	40.5	54.9	39.9	51.4	46.1	41.6	41.0
8	42.0	45.4	44.4	48.2	61.1	56.6	57.6	53.4	61.1	50.2	57.9	56.5	40.8
10	40.1	28.7	34.0	41.1	50.7	34.3	48.8	51.3	43.5	55.6	32.4	46.3	42.4
11	36.4	34.2	38.5	47.2	50.0	42.5	50.8	49.1	54.4	51.4	28.1	56.7	60.5
12	33.9	23.7	30.5	40.5	39.4	35.2	43.0	43.5	48.8	45.5	40.4	42.5	43.1
*13	29.6	30.9	32.3	43.6	39.4	41.0	41.2	50.4	56.1	47.7	38.9	55.9	53.4
*14		30.6	37.7	35.4	18.3	34.0	32.9	18.7	42.1	28.6	25.6	36.4	53.4
15	24.2	31.8	38.9	39.1	34.0	32.8	42.0	40.7	34.2	23.1	41.6	36.6	30.9
WEIGHTED	36.6	36.1	39.4	43.0	43.4	42.9	45.8	49.0	50.1	46.5	42.9	40.1	40.3